

LONG PERIOD BRAGG GRATING OPTICAL SIGNAL ATTENUATION**TECHNICAL FIELD**

The invention relates generally to fiber optics and more particularly to attenuation of optical signals.

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BACKGROUND

Optical components, for example, a fiber optic gyroscope, use optical signals generated by broadband fiber sources. In one design of a backwards pumped broadband fiber source, a light source sends pump light through a wave division multiplexing (“WDM”) fiber to a rare-earth doped fiber. The rare-earth doped fiber absorbs the pump light and emits the 10 output signals. This design suffers shortcomings from the use of the wave division multiplexing fiber to transmit the light for transmission to the rare-earth doped fiber. As one example, the wave division multiplexing fiber adds a significant cost to manufacture of the broadband fiber source. As another example, the wave division multiplexing fiber adds undesirable effects such as polarization splitting.

15 In one design of a forward pumped broadband fiber source, the light source sends the pump light directly to the rare-earth doped fiber. The forward pumped broadband fiber source omits the wave division multiplexing fiber of the design of the backwards pumped broadband fiber source discussed above. However, the light source comprises a facet face that, in this design, backreflects one or more of the output signals toward the fiber optic 20 gyroscope. The backreflection of the output signals causes an oscillation in the broadband fiber source, which disrupts operation of the fiber optic gyroscope.

Thus, a need exists for attenuation of optical signals to promote a reduction of backreflection. A further need exists for attenuation of optical signals with a reduced cost of manufacture.

SUMMARY

The invention in one implementation encompasses an apparatus. The apparatus comprises one or more light sources, one or more long period Bragg gratings that are optically coupled with the one or more light sources, and one or more amplification fibers
5 that are optically coupled with the one or more long period Bragg gratings. The one or more light sources send one or more pump optical signals to one or more of the one or more long period Bragg gratings. The one or more of the one or more long period Bragg gratings transmit the one or more pump optical signals to one or more of the one or more amplification fibers. The one or more of the one or more amplification fibers absorb one or
10 more of the one or more pump optical signals and emit one or more output signals. The one or more of the one or more long period Bragg gratings attenuate one or more of the one or more output signals.

Another implementation of the invention encompasses a method. A reduction of backreflection of one or more output signals from one or more amplification fibers of a
15 broadband fiber source is promoted through employment of one or more long period Bragg gratings.

DESCRIPTION OF THE DRAWINGS

Features of exemplary implementations of the invention will become apparent from the description, the claims, and the accompanying drawings in which:

20 FIG. 1 is a representation of one exemplary implementation of an apparatus that comprises one or more light sources, one or more long period Bragg gratings, one or more amplification fibers, and one or more optical components that are optically coupled with one another.

FIG. 2 is a representation of another exemplary implementation of the apparatus of FIG. 1 that further comprises one or more optical couplers and one or more optical circulators.

DETAILED DESCRIPTION

5 Turning to FIG. 1, an apparatus 100 in one example comprises a plurality of components such as hardware components. A number of such components can be combined or divided in the apparatus 100.

The apparatus 100 in one example comprises one or more light sources 102, one or more long period Bragg gratings 104, and one or more amplification fibers 108 that provide 10 light to an optical component 110. In a further example, the apparatus 100 comprises one or more long period Bragg gratings 106. The light sources 102, long period Bragg gratings 104 and 106, and amplification fibers 108 in one example are optically coupled with one another, for example, by a fiber optic cable or waveguide. For example, the light source 102 is optically coupled with the long period Bragg grating 104, the long period Bragg grating 104 15 is optically coupled with the amplification fiber 108, and the amplification fiber 108 is optically coupled with the optical component 110. In another example, the amplification fiber 108 is optically coupled with the long period Bragg grating 106, and the long period Bragg grating 106 is optically coupled with the optical component 110. In one example, the light source 102, the long period Bragg gratings 104 and 106, and the amplification fiber 108 20 are fusion-spliced to be optically coupled, as will be appreciated by those skilled in the art. The light source 102, long period Bragg gratings 104 and 106, and amplification fibers 108 in one example comprise a portion of a broadband fiber source 112.

The light source 102 in one example comprises a pump diode laser, for example, an indium gallium arsenide (“InGaAs”) laser diode. A front facet of the light source 102 in one 25 example comprises a surface that reflects optical signals. The light source 102 in one

example converts electricity into light, for example, one or more pump optical signals 114. The pump optical signals 114 in one example comprise a substantially same pump wavelength λ_p .

The long period Bragg gratings 104 and 106 comprise an optical core and a cladding 5 that covers the optical core. For example, the optical core comprises a higher refractive index than the cladding to promote total internal reflection of light within the optical core. The long period Bragg gratings 104 and 106 comprise corresponding wavelength attenuation ranges. For example, the optical core of the long period Bragg grating 104 couples optical signals with a wavelength within the wavelength attenuation range to the cladding to 10 attenuate the optical signals. The long period Bragg gratings 104 and 106 in one example attenuate the optical signals by twenty decibels, as will be appreciated by those skilled in the art.

The wavelength attenuation range of the long period Bragg gratings 104 and/or 106 in one example comprises a plurality of wavelength attenuation sub-ranges. For example, the 15 long period Bragg grating 104 is represented by a plurality of long period Bragg gratings. The plurality of long period Bragg gratings comprise the plurality of wavelength attenuation sub-ranges. The plurality of long period Bragg gratings are optically coupled in series to provide the wavelength attenuation range of the long period Bragg grating 104.

In one example, the wavelength attenuation sub-ranges are staggered to cover the 20 wavelength attenuation range. For example, none (i.e., zero) of the wavelength attenuation sub-ranges overlap. In another example, one or more of the wavelength attenuation sub-ranges overlap a portion of an adjacent wavelength attenuation sub-range. For example, a first long period Bragg grating provides a lower sixty percent of the wavelength attenuation range and a second long period Bragg grating provides an upper sixty percent of the

wavelength attenuation range, and a central twenty percent of the first and second wavelength attenuation ranges is overlapped by the first and second long period Bragg gratings.

The amplification fiber 108 in one example comprises a rare earth doped fiber, for example, an erbium or neodymium doped fiber. The amplification fiber 108 receives and 5 absorbs one or more optical signals and emits a plurality of output signals, for example, output signals 116 and 118, through amplified spontaneous emission. In one example, the amplification fiber 108 directs the output signals 116 towards the long period Bragg grating 104. In a further example, the amplification fiber 108 directs the output signals 118 towards the optical component 110. The output signals 116 and 118 comprise a substantially same 10 signal wavelength λ_s . The wavelength λ_p and the wavelength λ_s comprise different wavelengths, as will be appreciated by those skilled in the art.

The optical component 110 in one example comprises a fiber optic gyroscope. The optical component 110 employs one or more optical signals of wavelength λ_s to perform a task, for example, to determine a magnitude of rotation. The optical component 110 returns 15 one or more of the optical signals to the broadband fiber source 112. For example, the optical component 110 employs one or more of the output signals 118 to determine a magnitude of rotation.

An illustrative description of exemplary operation of the apparatus 100 is presented, for explanatory purposes. The light source 102 generates one or more pump optical signals 20 114 of wavelength λ_p and sends the pump optical signals 114 towards the long period Bragg grating 104. The wavelength attenuation range of the long period Bragg grating 104 omits the wavelength λ_p , and the long period Bragg grating 104 transmits the pump optical signals 114 to the amplification fiber 108..

The amplification fiber 108 absorbs one or more of the pump optical signals 114. 25 Through amplified spontaneous emission, the amplification fiber 108 emits a plurality of

output signals, for example, output signals 116 and 118. The amplification fiber 108 directs the output signals 116 towards the long period Bragg grating 104 and directs the output signals 118 towards the optical component 110 through the long period Bragg grating 106.

The wavelength attenuation range of the long period Bragg grating 104 comprises the signal wavelength λ_s of the output signals 116. The long period Bragg grating 104 attenuates the output signals 116 and creates one or more output signals 122. The front facet of the light source 102 causes a backreflection of one or more of the output signals 122, for example, output signals 124, toward the long period Bragg grating 104, as will be appreciated by those skilled in the art.

The long period Bragg grating 104 attenuates the output signals 116 to promote a reduction of backreflection of the output signals 116 incident on the front facet of the long period Bragg grating 104. The long period Bragg grating 104 attenuates the output signals 124 and creates one or more output signals 126. The long period Bragg grating 104 attenuates the output signals 116 and 124 to promote a reduction of oscillation of the output signals 116, as will be appreciated by those skilled in the art.

The wavelength attenuation range of the long period Bragg grating 106 in one example omits the wavelength λ_s and the long period Bragg grating 106 transmits the output signals 118 to the optical component 110, as will be appreciated by those skilled in the art. The optical component 110 employs the output signals 118 to perform a task, and returns one or more of the output signals 118, for example, one or more output signals 130, to the broadband fiber source 112. The long period Bragg grating 104 attenuates the output signals 130 analogous to the output signals 116.

The amplification fiber 108 in one example transmits one or more residual signals 132 of the pump optical signals 114. The wavelength attenuation range of the long period Bragg grating 106 in one example comprises the wavelength λ_p . The long period Bragg grating 106

attenuates the residual signals 132 and creates one or more residual signals 134. Where the optical component 110 comprises a fiber optic gyroscope, the long period Bragg grating 106 attenuates the residual signals 132 to promote a reduction of a scale factor linearity error of the fiber optic gyroscope.

5 Turning to FIG. 2, the apparatus 100 in another example comprises one or more light sources 102, one or more long period Bragg gratings 104 and 106, one or more amplification fibers 108, one or more optical components 202, and one or more optical couplers 204 that provide light to an optical component 110. The optical component 202 in one example comprises a multi-function integrated optic chip and one or more portions of an optical fiber 10
10 or waveguide. The optical component 202 redirects optical signals from the long period Bragg grating 106 back into the long period Bragg grating 106. The optical coupler 204 redirects optical signals from the long period Bragg grating 106 to the optical component 110.
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The light source 102 generates pump optical signals 114, analogous to FIG. 1. The amplification fiber 108 absorbs one or more of the pump optical signals 114 and emits the output signals 118. The amplification fiber 108 transmits the residual signals 132 to the long period Bragg grating 106. The long period Bragg grating 106 transmits the output signals 118 to the optical component 202. The optical component 202 redirects the output signals 118 back into the long period Bragg grating 106 toward the optical coupler 204. The optical 20 coupler 204 redirects the output signals 118 to the optical component 110.

The long period Bragg grating 106 attenuates the residual signals 132 and creates one or more residual signals 134. Where the optical component 110 comprises a fiber optic gyroscope, the long period Bragg grating 106 attenuates the residual signals 132 to promote a reduction of a scale factor linearity error of the fiber optic gyroscope. The optical component 25 202 redirects the residual signals 134 back into the long period Bragg grating 106 toward the

optical coupler 204. The long period Bragg grating 106 attenuates the residual signals 134 and creates residual signals 208. The optical coupler 204 redirects the residual signals 208 to the optical component 110.

The steps or operations described herein are just exemplary. There may be many
5 variations to these steps or operations without departing from the spirit of the invention. For instance, the steps may be performed in a differing order, or steps may be added, deleted, or modified.

Although exemplary implementations of the invention have been depicted and described in detail herein, it will be apparent to those skilled in the relevant art that various
10 modifications, additions, substitutions, and the like can be made without departing from the spirit of the invention and these are therefore considered to be within the scope of the invention as defined in the following claims.